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ABSTRACT

This study investigates whether color and background information in motion visuals have different effects on memory and comprehension of students in various grade levels. A three-by-three factorial pretest-posttest design was used, comparing levels of visual complexity and grade levels. The instructional content was a 12-minute computer animation concerning life styles of animals. A total of 412 third, sixth, and eighth graders were randomly assigned to one of three treatment groups: simple group; simple with color group; and simple with color and background information group. All subjects received a pretest, treatment, and two posttests. The posttests were designed to test the subject's memory and comprehension of the instructional content. In addition, a questionnaire was administered to the subjects in order to understand their perceptions of visual complexity in the treatment. Results indicate that there was interaction between amount of visual complexity in motion visuals and grade level. Color and background information affected the third graders' achievement in memory and comprehension differently, while both the sixth and eighth graders' performance was not at all affected by the amount of visual complexity in motion visuals. (Contains 28 references.) (Author)

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The Effects of Color and Background Information in Motion Visuals on Children's Memory and Comprehension

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Abstract

The purpose of this study was to investigate whether color and background information in motion visuals have different effects on memory and comprehension of students in various grade levels. A 3 (levels of visual complexity) X 3 (grade levels) factorial pretest-posttest design was used. The instructional content was a 12-minute computer animation concerning life styles of animals. A total of 412 third, sixth and eighth graders was randomly assigned to one of the three treatment groups. They were simple group, simple with color group, and simple with color and background information group. All subjects received a pretest, treatment, and two posttests. The posttests were designed to test subject's memory and comprehension of the instructional content respectively. In addition, a questionnaire was also administered to the subjects in order to understand their perceptions of visual complexity in the treatment. The results of this study indicated that there was interaction between amount of visual complexity in motion visuals and grade level. Color and background information would affect the third graders' achievement in memory and comprehension differently, while both the sixth and eighth graders' performance were not affected by the amount of visual complexity in motion visuals at all.

Introduction

With the enormous utilization of visual communications in learning environments, today visual messages have become an important medium, besides verbal and written language, for communicating instructional information to students. However, many researchers of visual instruction found that the use of visuals was not a panacea for improving student achievement (Dwyer, 1978; Levie & Lentz, 1982; Peeck, 1987). The various visual variables play a significant role in student's ability to memorize and comprehend the instructional materials.

There are two attributes in visual complexity which have been recognized by researchers as important factors influencing learner's processing of visual information. They are color and background information (Dwyer, 1978; Fleming, 1987; Tullis, 1981; Jones, 1989; Franken, 1977). The environment in which we live is colorful. Consequently, most visuals used for instructional purposes is now in color. The uses of color in a visual can be decorative, affective, attentional and cognitive (Pettersson, 1989; Pruisner, 1993). However, there has been considerable debate about the effectiveness of color as an attribute of visual information. Tullis (1981) indicated that the effectiveness of color was highly dependent on the task for which it was used. He concluded that color could be beneficial to performance, but no more so than shape coding. Livingston (1991)

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also found that color appeared to be a distracting variable because learners could often remembered the color of a hidden object while forgetting what the object was itself. On the other hand, Pruisner (1993) reported that the use of color had a positive impact on the recall of verbal information presented in graphic form. After conducting over 100 studies in this area, Dwyer (1982-83) also concluded that for the specific types of educational objectives the use of color had been found to be an important variable for improving student achievement. However, whether effects of color in instructional materials interact with learner age and cognitive levels is still unanswered. Thus, research into color as an instructional attribute is far from conclusive.

The influence of background information on cognitive learning is another issue examined in the research on visual complexity. Many researchers have indicated that perception of a visual is determined not only by its characteristics but also by its surrounding context (Fleming, 1987; Antes & Metzger, 1980; Pettersson, 1989). A number of empirical investigations have focused on the presence or absence of background information in visuals. One of the earliest studies was conducted by Spaulding (1956). He found that visual information unnecessary to critical figures should be eliminated because it may motivate an interpretation that was not compatible with the purpose of the illustration. However, Antes & Metzger (1980) indicated that the context of objects helped learners construct a general characterization of the pictures which provided learner expectancies to perform their discrimination task. In general, the research results in this area are inconclusive and usually contradict one another .

Furthermore, many studies also indicate that there are developmental changes associated with how children perceive visuals of different amount of complexity (Pettersson, 1989; Collins, 1970; Miller & Burton, 1994). Although the research results appear inconsistent to some extent, researchers agree that there are age differences in how the children allocate their attention to a visual task. In addition, according to the findings of prior studies (Chen, 1993; Hozaki, 1988), there is an indication that humans may employ different internal cognitive processes for memorizing than for comprehending a visual display. However, as Shuell (1986) has indicated , it is not clear how these two mental processes are different. Does the visual information play dissimilar roles during these processes? It is evident that more research has to be done before we can draw a general conclusion on these issues.

Another limitation of the prior research concerning the effects of visual complexity on cognitive learning is the static visual stimuli used as the material to be memorized or comprehended. Only a few studies have attempted to investigate the relative effectiveness of motion visuals that employ different levels of visual complexity to complement verbal instruction (Stone, 1983; Acker & Klein, 1986; Chen, 1993). In view of the increasing use of motion visuals in school settings, there is no doubt that more research work needs to be conducted regarding how students acquire learning information from moving visuals.

In summary, for lack of thorough and conclusive empirical evidence concerning effects of visual complexity on cognitive learning tasks across age levels, teachers and instructional designers usually rely on their intuition in deciding how to select and present visuals in instructional materials. Therefore, it is evident that there is need to further investigate this area.

Research Questions

The purpose of this study was to investigate whether differences in the level of visual complexity in motion visuals have different effects on memory and comprehension of students in various grade levels. Specific questions related to the problems were as follows:

1. Does the addition of colors in motion visuals have an effect on students' ability to memorize and comprehend the instructional materials?
2. Does the addition of background information in motion visuals have an effect on students' ability to memorize and comprehend the instructional materials?
3. Does the effect of visual complexity in motion visuals relate to students' age?
4. Does visual complexity in motion visuals play different roles in the processes of memorizing and comprehending?

Methods

Subjects

Subjects for the study consisted of 412 third (N=131), sixth (N=133) and eighth (N=148) graders from three public schools in Taiwan. They all were average students and were randomly chosen by school curriculum coordinators.

Instructional Content

The instructional content for this study was a 12-minute computer animation concerning life styles of animals, such as migration, classification, protective coloring , running speed. The main reason for selecting this topic was that movement was a defining attribute of the concept taught in the lesson. Furthermore, in order to examine the subjects' both memory and comprehension achievement, the instructional content was not presented through the method of direct instruction. Instead, it was displayed through a series of short events happened during a swallow's journey.

Instructional Treatment

The treatments for this study were created using the Animator Pro program that runs on a PC environment. There were three versions of color computer animation representing three levels of visual complexity for this study. They were outline drawing (OD), outline drawing with color (ODC), and outline drawing with color and background information (ODCB).

In the OD version, the computer animation retained only the outline shapes of critical objects necessary to convey the main meaning of the narration (see Figure 1). The ODC treatment was the one in which different colors were added to the outline shapes of the first version (see Figure 2), and the third was the version in which both colors and background information were added (see Figure 3). Although the three versions of the treatment had different levels of visual complexity, they all employed the identical narration to complement the visual information.

Figure 1. A Sample Frame in Outline Drawings (OD)

Figure 2. A Sample Frame in Outline Drawings with Color (ODC)

Figure 3. A Sample Frame in Outline Drawings with Color and Background Information (ODC)

Instrumentation

There were four instruments used in this study. They were pretest, memory test, comprehension test, and questionnaire. The pretest consisted of only 10 multiple-choice questions which tested students' prior knowledge about the instructional content. The memory test (KR20= .80) was designed to test students' memory of content which was presented in the computer animation. There were 33 multiple-choice questions in this test. The comprehension test (KR20= .85) was composed of 25 multiple-choice items which measured students' comprehension of instructional content. The fourth instrument was the questionnaire used for obtaining students' perceptions of the computer animation. The questionnaire contained 3 open-ended questions, such as did you think whether the screen of the computer animation would be to boring or too complex; did you want to continue watching the animation? Why; of the whole story, which part did you remember most.

Procedure

The subjects of third , sixth and eighth graders were randomly assigned to one of the three treatments respectively. Then they received a pretest to determine their prior knowledge level in the instructional content. However, since the possibility existed that the pretest might activate student's attention toward some specific areas of the computer animation, the pretest was administered four weeks before the experimental treatments were delivered.

After four weeks, subjects received their respective experimental treatments and two posttests (memory and comprehension tests). Upon the completion of the experiment, several students from each experimental group were randomly selected to answer the open-ended questions in the questionnaire. The researchers and two assistants encouraged these subjects to express their opinions to the computer animation and write these responses down in the questionnaire.

Results

The design of the study was a 3 (levels of visual complexity) X 3 (grade levels) factorial pretest-posttest design. In order to determine whether there were existing group differences in achievement levels of subjects in different treatments, an ANOVA procedure was utilized. The results showed a nonsignificant difference, $F(2,403)= .06$, $p=.9427$, for pretest scores among the three treatment groups. Therefore, the statistical results for this study were analyzed using ANOVA for main effects and their interactions. In addition, a post hoc Scheffe method was used to test for differences between pairs of means.

Analysis of Memory Test Results

The memory test means and standard deviations for the three treatment groups by grade levels were presented in Table 1. Summary ANOVA statistics were shown in Table 2. As shown in Table 2, there were significant differences for the main effect of grade and interaction effect of treatment and grade. Therefore, the simple main effects were further examined and the results reported in Table 3. According to Table 3, three

obtained F ratios were significant. They were the 3rd grade in treatment conditions as well as the OD and ODCB groups in grade levels.

Table 1. Memory Test Means and Standard Deviations by Treatment Condition for Grade 3, 6, and 8

	OD			ODC			ODCB	
	N	M	SD	N	M	SD	N	M	SD
3rd Grade	45	21.69	5.96	43	25.37	4.24	45	22.93	4.99
6th Grade	44	27.00	3.63	44	25.68	4.78	43	25.14	4.11
8th Grade	49	25.96	3.87	48	25.88	4.60	51	27.43	2.57

Table 2. Analysis of Variance of Treatment Condition and Grade Level for Memory Test

Source	SS	DF	MS	F	P
Treatment	40.11	2	20.06	1.05	0.3521
Grade	754.70	2	377.35	19.69**	0.0001
Treatment x Grade	427.50	4	106.87	5.58**	0.0002
Error	7722.88	403	19.16		

**P<.01

Table 3. Analysis of Variance of Simple Main Effect for Memory Test

Source	SS	DF	MS	F	P
Treatment					
3rd Grade	323.64	2	161.82	8.44**	0.000
6th Grade	81.00	2	40.50	2.11	0.122
8th Grade	82.87	2	41.44	2.16	0.116
Grade					
OD	711.41	2	355.71	18.56**	0.000
ODC	6.76	2	3.38	0.18	0.838
ODCB	483.93	2	241.97	12.63**	0.000
Error	7722.88	403	19.16		

**P<.01

Since the number of subjects in each treatment groups were different, the Scheffe method was used to test for differences between pairs of means. The results were as following:

1. In the third grade , the ODC treatment surpassed the OD and ODCB treatments. As for the sixth and eighth grades, the three treatment groups performed in similar ways.

2. For the OD treatment, the third graders' performance was inferior than the sixth and eighth graders' performance. For the ODC treatment, there was no significant difference among grade levels. The eighth graders in the ODCB treatment exceeded other two grade levels.

Analysis of Comprehension Test Results

The comprehension test means and standard deviations for the three treatment groups by grade levels were presented in Table 4. Summary ANOVA statistics were shown in Table 5. As shown in Table 5, there were significant differences for the main effect of grade and interaction effect of treatment and grade. Therefore, the simple main effects were further examined and the results reported in Table 6. According to Table 6, three obtained F ratios were significant. They were the 3rd grade in treatment conditions as well as the OD and ODCB groups in grade levels.

Table 4. Comprehension Test Mean and Standard Deviation by Treatment Condition for Grade 3, 6, and 8

	OD			ODC			ODCB		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
3rd Grade	45	12.44	5.24	43	15.49	5.57	45	15.02	4.93
6th Grade	44	18.30	4.39	44	17.07	5.50	43	16.42	5.03
8th Grade	49	18.41	4.48	48	17.65	4.92	51	19.04	3.61

Table 5. Analysis of Variance of Treatment Condition and Grade Level for Comprehension Test

Source	SS	DF	MS	F	P
Treatment	15.11	2	7.55	0.32	0.7269
Grade	1204.97	2	602.48	25.47**	0.0001
Treatment x Grade	349.89	4	87.47	3.70**	0.0057
Error	9533.99	403	23.66		

**P<.01

Table 6. Analysis of Variance of Simple Main Effect for Comprehension Test

Source	SS	DF	MS	F	P
Treatment					
3rd Grade	250.70	2	125.35	5.30**	0.005
6th Grade	80.17	2	40.08	1.69	0.185
8th Grade	55.22	2	27.61	1.17	0.312
Grade					
OD	1056.03	2	528.02	22.32**	0.000
ODC	111.99	2	56.00	2.37	0.095

ODCB	407.93	2	203.96	8.62**	0.000
Error	9533.99	403	19.16		

**P<.01

Since significant F ratios were found, differences between pairs of means were analyzed via Scheffe procedure. The results were as following:

1. In the third grade , the OD treatment performed worst among the three treatments, while the performance of the ODC and ODCB treatments was no different. In the sixth and eighth grades, the three treatment groups performed in similar ways.
2. For the OD treatment, the third graders' comprehension performance was the worst among the three grade levels. For the ODC treatment, there was no significant difference among grade levels. The eighth graders in the ODCB treatment exceeded substantially the third and sixth graders.

Analysis of Questionnaire

An analysis of the data from the questionnaire revealed the following findings:

1. Most students in each grades liked the computer animation because it was presented through a story style.
2. The OD groups at each grade levels perceived the level of visual complexity in the computer animation was too dull. The reason why students wanted to continue watching the animation was that they would like to know more about animals they were not quite familiar with yet.
3. Third graders preferred the ODC version and indicated that the visuals in the ODCB version were too complex. However, the sixth and eighth graders prefer visuals with background information and indicated that the visual complexity and color in the ODCB were just right.
4. The instructional contents of the computer animation remembered most by the students was the knowledge they did not possess before, such as a giraffe having four stomachs.

Discussion

Level of Visual Complexity in Motion Visuals and Grade Level

The results of this study indicated that children by sixth grade had acquired the ability to selectively process visual information. This finding was different from some earlier research which had previously reported that only until adolescence did children show the efficient use of selective attention to a learning task (Collins, 1970; Hale & Taweel, 1974; Hagen, 1972). A possible reason accounting for the developmental advance may have been that with the increasing impact of visual messages in our society, visual instruction has become one of the major methods of communicating information. Therefore, under such a learning environment, children capable of selectively allocating their attention were younger than ones in the 1970s. This finding verified what Hurt (1991) has stated that the amount of experience children brought to would affect them interpreting visual information.

Furthermore, the post hoc analysis of this study indicated that third-grade students in the OD group performed much worse on both memory and comprehension tests than students in sixth- and eighth-grade, while in the ODC version, the three age groups performed equally well. In term of the levels of visual complexity, the third graders' memory performance in the ODC treatment surpassed in the OD and ODCB treatments; their comprehension performance in the ODC and ODCB treatments exceeded in the OD treatment. Thus, although the prior research suggested a visual presentation should be simple enough so that only the information relevant to the learning task was provided (Spaulding, 1956; Travers & Alvarado, 1970), the present study found that the addition of colors in motion visuals can help third-graders memorize and comprehend the instructional materials. There were two possible explanations which may illustrate this situation. First, some research found that since chromatic information can delineate figure/ground relationships, it appeared to aid cognitive tasks such as recall, free association, and recognition memory (Stone, 1983; Pruisner, 1993). Furthermore, research also indicated that the younger children recalled the visual information by color more quickly than by shape (Pick, Christy & Frankel, 1972).

The second likely reason was that due to the rapid advances in technology recently, visual information was often displayed by adding more and more details, colors etc. Therefore, children may feel uncomfortable watching instructional material without vivid chromatic information. As a result, visual information with only outline drawings may not motivate students by fourth-grade to learn the instructional contents.

The Effects of Visual Information on Memory and Comprehension

The data analysis of this study shown that visual complexity in motion visuals had different effects on third graders' memory and comprehension. The addition of colors appeared to aid subjects memorizing and comprehending the learning contents, but the additional background information contributed only to higher level cognitive tasks such as comprehension.

Gorman (1973) has suggested a tolerance level hypothesis to explain the nonsignificant research results on the relationship between pictorial detail and grade level. That is, due to a tolerance level existing for some irrelevant information in a picture, the irrelevant detail may not interfere with learner's processing of the relevant information presented. Chen (1993) has inquired whether the tolerance level hypothesis associated with cognitive level of the task. The findings of this study verified this inquiry. In term of third-grade's memory learning, the level of visual information contained in the ODC version was just adequate, while the information in the ODCB was at the extreme end of third-graders' tolerance level. Therefore, students' memory performance in the ODCB was worse than in the ODC. However, in term of comprehension learning, third graders' tolerance level for some irrelevant visual information was higher. Thus, the learning performance in the ODC and ODCB exceeded in the OD treatment. In other words, the addition of background information in visuals may not interfere with third-grade children's comprehension learning.

Why does visual complexity have different effects on memory and comprehension learning? Miller and Burton (1994) suggested one possible explanation that the speed and accuracy of recall was directly dependent upon how the information was encoded and the attention being given to the stimulus. Therefore, in term of the memory level, irrelevant information in the instructional material may distract student' attention from the

essential information. Such information could not promote memorizing the instructional material and may even interfere with it. In contrast, in term of the cognitive level of comprehension, Ellis and Hunt (1993) indicated that comprehension was the process of extracting the general meaning of a communication and distract details. Thus, the addition of visual information may not have negative influence on the process of comprehension. In other words, children's tolerance level was higher in comprehending the learning tasks than in memorizing them. Furthermore, Dwyer (1978) has stated that "....(comprehension) did not require student to utilize effectively the information presented in the illustration" (p.33). However, from the results of this study, it showed that children's tolerance level may be one of the possible explanation.

Educational Implications and Recommendations

There were several important implications and recommendations for educational researchers and instructional designers to consider from the results of this study.

1. Instructional visuals in motion visuals selected for third graders or younger should be rich, colorful imagery in order to attract their attention and improve their achievement.
2. For children by six grade, visual complexity in motion visuals may not be an important factor to be considered, because they have acquired the ability to process visuals effectively.
3. Visual complexity in motion visuals affect third grader's memory and comprehension differently. Therefore, whether to include background information in instructional visual messages depends on the types of instructional objectives.
4. Since the subjects selected for this study were normal students, the same research could be conducted with special children with different areas of retardation.

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